OCEAN RIDGES

Anomalous Uranium

from our Geomagnetism Correspondent

THE recent discovery by Boström and Fisher (*Nature*, **224**, 64; 1971) of unusually high uranium concentrations in East Pacific Rise sediments has inevitably raised the question of the origin of the "excess" uranium. Could it, for example, have been derived from volcanic processes? The first thing to be said about this hypothesis is that there is not a shred of direct evidence for it. On the other hand it is known that volcanic emanations have enriched ridge crest sediments in elements such as iron and manganese; and this could be taken as circumstantial evidence for volcanic uranium enrichment. There are, however, other possible sources for the excess uranium. Ku, for example (in *Hot Brines and Recent Heavy Metal Deposits in the Red Sea*, Springer, New York, 1969), recently suggested that the high concentrations of uranium in iron-rich deposits from the Red Sea geothermal area might be attributable to the deposition of uranium from seawater by coprecipitation with ferric iron.

Veeh and Boström (*Earth Planet. Sci. Lett.*, **10**, 372; 1971) now suggest that Ku's mechanism may well be applicable to the East Pacific Rise sediments; and from a new series of analyses of sediments and iron deposits show that this is highly likely in most—but not all—cases. The $^{234}U/^{238}U$ ratio in seawater is constant at 1.15 ± 0.02, so that measurement of this ratio in newly formed sediments should presumably reflect this value in some way. In fact, in all but one of Veeh and Boström's samples, $^{234}U/^{283}U$ ratios lie between 1.00 and 1.14—in other words, they are less than but approaching the constant oceanic value. These compare with values of unity or less for pelagic clays but are in line with values from the Red Sea geothermal deposits. A seawater origin thus seems reasonable.

Unfortunately, seawater cannot be the whole story, for one iron deposit dredged from the flank of a seamount on the crest of the East Pacific Rise has a $^{234}U/^{238}U$ ratio of 1.21. Strangely, Bonatti and Joensuu (*Science*, **154**, 643; 1966) ascribed this iron deposit to submarine volcanism, probably produced by an interaction between hydrothermal solutions and seawater. Yet, clearly, its uranium cannot be derived completely from the seawater. In this one case therefore volcanic processes become a real possibility, although, as Veeh and Boström point out, one of at least two different volcanic processes could be applicable.

The first appeals to fractionation of uranium isotopes during volcanic activitv. Fractionation is quite common in weathering processes and seems to be the principal cause of the 15 per cent excess of ^{234}U over ^{238}U in seawater. It turns out, however, that it would not be possible to derive all of the excess ^{234}U by such a mechanism; and to overcome this objection Ku suggested (*J. Geophys. Res.*, **70**, 3457; 1965) that additional ^{234}U might be derived by the preferential leaching of ^{234}U from deep sea sediments and its subsequent diffusion into the bottom waters. Whether the sort of fractionation processes which take place during weathering also take place during magmatic activity is unknown, however, though they remain a possibility.

In fact, an appeal to magmatism as such is unnecessary. Thus Veeh and Boström suggest the preferential leaching of ^{234}U from wall rocks by rising hydrothermal fluids associated with submarine volcanism. The uranium is then coprecipitated with ferric iron upon contact with seawater. In general the uranium derived from seawater in the normal way will mask that produced by the hydrothermal process because of rapid mixing of the fluids with the bottom waters. But the question that Veeh and Boström ask is: could the iron be precipitated so quickly that such mixing would not have time to take place? They suppose it could—and thus that the precipitating iron could "grab" the hydrothermal uranium before it becomes dispersed in the seawater.

Angles on Pulsars

Two contradictory views of the same problem—the emission mechanism of the pulsar in the Crab Nebula—are published in next Monday's *Nature Physical Science*. Both articles include as evidence the characteristic polarization of the three subpulses that make up the pattern of emission from the pulsar at optical and radio wavelengths. And both are founded on the view that the Crab Nebula pulsar is a rapidly rotating star having a dipole magnetic field oriented at an angle to the rotation axis. R. N. Manchester of the National Radio Astronomy Observatory, however, argues that the magnetic and rotation axes are at right angles, whereas in the following article F. G. Smith (Jodrell Bank) concludes that the angle between them is likely to be about 45°.

The chief difference betwen their approaches is that Smith concentrates on a relativistic approach already set out in detail in *Monthly Notices of the Royal Astronomical Society* (**149**, 1; 1970). In brief, Smith has been canvassing support for the view that the source of the pulsar emission is radiating isotropically in its own frame of reference, but which appears to be emitting a beam when viewed from the Earth. The relativistic velocities needed for this mechanism are acquired by sources rotating with the star, but some distance from it; the Crab pulsar completes one revolution every 33 ms, so the possibility of material spinning with the star at a tangential velocity approaching *c* has to be taken into account.

Next Monday Smith takes the story a step further when he shows that relativistic effects should also be allowed for in evaluating the expected position angle of linearly polarized components of the emission. His interpretation of the quite characteristic swing of the polarization through the pulses which is observed leads to the view that the radiating source is located away from the polar magnetic field lines, that the line of sight to the pulsar is at an angle of 20°–30° to the rotation equator, and that the axis of the magnetic dipole is inclined at something like 45° to the rotation axis.

But in the preceding article Manchester bases his interpretation of the polarization measurements on the view that the optical and radio emission both come from nearer the surface of the star, and in the vicinity of the magnetic poles rather than away from them. He argues that both the optical and the radio signals are emitted essentially tangentially to the field lines, so that at the peak of the pulses the line of sight must be almost directly down onto the magnetic pole. The way in which the position angle alters across the pulses in different ways at optical and radio wavelengths is accounted for by the basic synchrotron emission arising in different ways in the two bands.

The pattern of the variation in position angle of the optical pulses also suggests to Manchester that the orientation of the field lines in the region where the optical radiation is being emitted is slightly different from the orientation associated with the radio emission. Possibly the optical emission is occurring further out from the surface of the star, but nevertheless still along the same polar field lines as the radio emission, in contrast to the argument in Smith's article that the source is away from the polar field lines.

Manchester goes on to point out that if the radio and optical pulses come from different regions above the magnetic poles, and if the emission is tangential to the field lines, then in the case of the Crab pulsar radio and optical pulses will only be seen together if the rotation axis is at right angles to the magnetic axis.